CHESIL BEACH: ASPECTS OF ITS STRUCTURE, STABILITY AND THE PROCESSES ACTING UPON IT

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INTRODUCTION

Much of the geological, geomorphological and historical data concerning Chesil Beach and the Fleet lagoon (Fig 1) have been summarised in Carr and Blackley (1974). The purpose of the present Chapter is to briefly state some of the salient conclusions concerning the beach derived from that paper without further discussion, and then to concentrate in slightly more detail on three aspects where more information has become available.

Chesil is essentially a simple, linear, shingle storm beach which, because it links the so-called Isle of Portland with land much further west, is frequently quoted as an example of a tombolo. Although the pebble and cobble feature is joined to the mainland at Abbotsbury and Chiswell, over the intervening 13 km it is backed by the shallow, tidal, Fleet. Opposite the Fleet, Chesil Beach is between 150 and 200 m wide, but it is narrower both adjacent to the cliffs in the west and at its extreme eastern end. The crest is intermittent at the western end but becomes continuous from midway between West Bexington and Abbotsbury, to Chiswell. The general picture is of a progressively increasing ridge height from W to E with the maximum some 14 m above mean sea level. The pebble size above low water mark coarsens in the same direction with the most rapid rate of change at the Chiswell end. Mean long diameter at Chiswell (Section 1) is of the order of 5 cm, falling to 3.5 cm by Section 2 and rather under 2.5 cm by Section 7 (Carr 1969). Offshore the beach drops at a broadly similar gradient to that of the seaward face above low water mark before shelving gradually to about -18 m some 270 m offshore of Wyke Regis and -11 m at a similar distance off West Bexington.

On the basis of records extending over a 2 year period Hardcastle and King (1972) showed that the most frequent wave period was between 10.00 and 10.50 seconds and that 50 per cent of the significant waves (H_s) exceeded 0.26 m at Wyke and 0.23 m at West Bexington. At the latter site 2.7 per cent exceeded 2m, with maximum wave height (H_{max}) calculated as approximately 8 m at some time during the observation period.

SOME FIRMLY BASED VIEWS

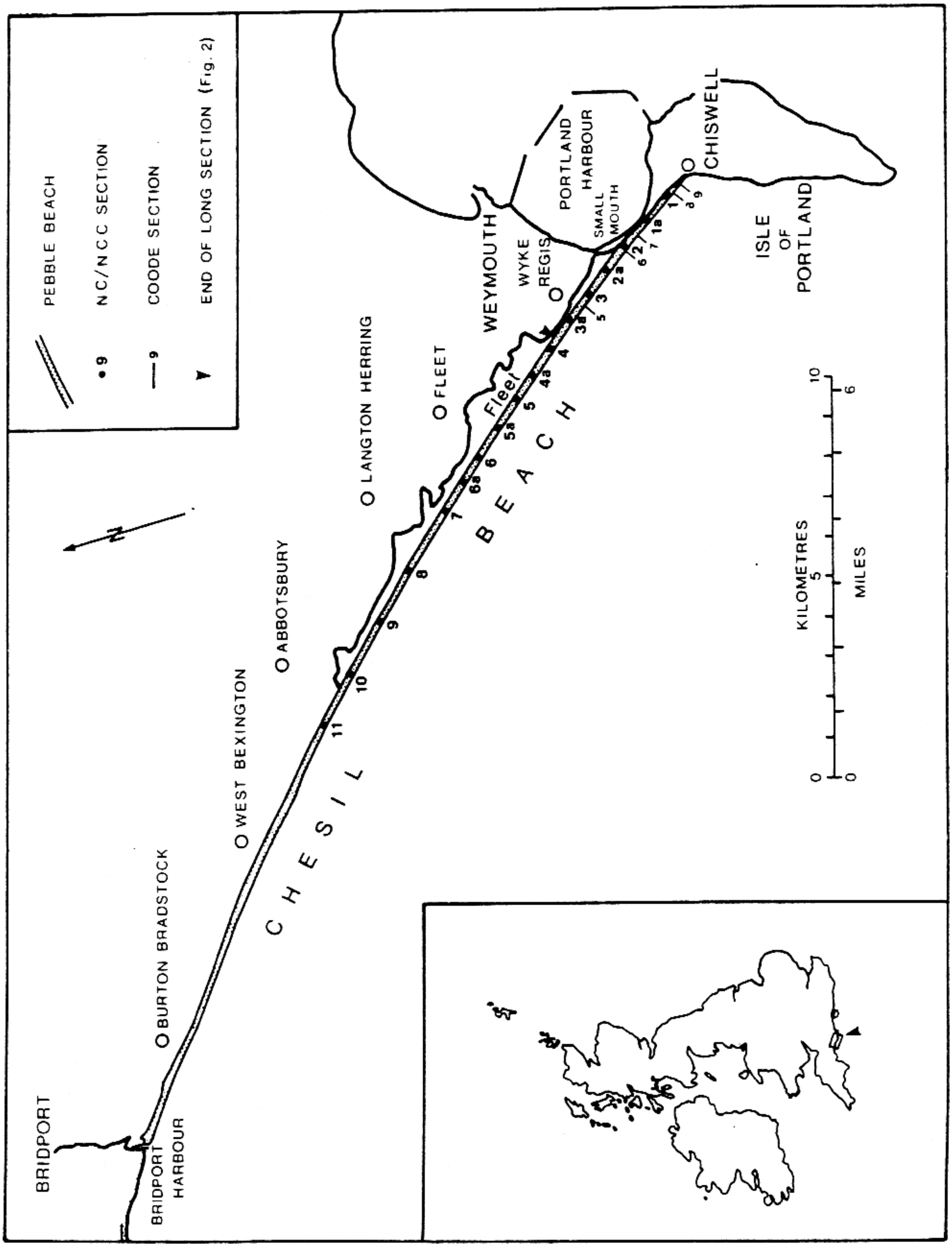
Although argument remains as to other aspects of investigation and to detail, research prior to 1974 indicates that:

(a) The western limit of the beach is arbitrary, depending upon the criteria used to define it (eg consistency in the longshore size grading of the beach material or the continuity of the crest line). It has been drawn variously at Abbotsbury, West Bexington (on the basis of longshore sediment size grading), Burton Cliff, and West Bay, and may be changing with time. Thus, as the beach advances very gradually towards its hinterland the various segments between Abbotsbury and West Bay become more isolated one to another and to the main stretch of Chesil Beach further E. The evidence indicates that there have been various potential sources of material, including fluvial as well as marine deposits, and the relative significance of these sources is likely to have varied with time over the long-term. Although the bulk of the material, some 98 per cent, is chert and flint which could have been derived from a number of primary (and secondary) sources the diagnostic rocks, eg Triassic quartzites, are all derived from the SW. In general, there appears to be little appropriate material now available to nourish the beach from offshore.

Borehole samples show that pebbles become more angular with depth and at these lower levels they are then derived from more local, less resistant, geological strata. This implies that attrition is of some importance as a cause of loss of volume of the beach, at any rate in the long-term. The boreholes also indicate that the massive pebble and cobble deposits are concentrated in the exposed, ie sub-aerial, part of Chesil Beach. Although shingle is present below low water mark it is as limited, discontinuous, horizons. (This explains why estimates for shingle volume range between about 25 and 100 million tonnes; the volume of deposits below mean sea level is not adequately known from existing borehole coverage.)

(b) There is evidence to suggest that there have been various changes in the crest height of Chesil Beach over the last 300-400 years and that at one time the crest may have been lower over most of the length between Abbotsbury and Portland. Although the total volume of beach material appeared to change very little between Sir John Coode's survey of 1852 and one in 1968-9 the crest height between Abbotsbury and Wyke Regis showed a substantial increase. This was of the order of 2 m at Langton Herring. Between Langton Herring and E of Wyke Regis there was a rise, typically of 1.5 m, but near Chiswell a drop of 0.5 m, reaching an extreme fall of 3.5 m at one point, was recorded. New data is available on this aspect and is discussed below.

Fig 1


PEBBLE BEACH
NC/NCC SECTION
COODE SECTION
END OF LONG SECTION (Fig. 2)
BRIDPORT
BRIDPORT HARBOUR
BURTON BRADSTOCK
WEST BEXINGTON
ABBOTSBURY
LANGTON HERRING
FLEET
Fleet
WEYMOUTH
WYKE REGIS
PORTLAND HARBOUR
SMALL MOUTH
CHISWELL
ISLE OF PORTLAND
CHESIL BEACH
N
KILOMETRES
MILES
0
5
10
6

(c) There has been considerable disagreement about the nature and cause of longshore grading of beach pebbles and cobbles. However, recent work at Chesil confirms that, providing wave energy is high enough to move coarse material, the largest fraction on the exposed beach will move faster. Longshore transport is also dependent upon the angle of wave approach relative to the shoreline.

Grading alongshore is restricted to the zone above low water mark. It is not true that the direction of grading is reversed below low water; rather that there is no grading there (Neate, 1967).

In tracer experiments near Wyke Regis, approximately Section 4 in Figure 1, longshore movement was predominantly towards the SE, ie in the direction of coarsening of particle size of the natural beach material, although coarsening of tracer pebbles towards the NW was recorded at one time. At Portland, where waves approach approximately normal to the beach, lateral transport was much more random in its nature (Carr, 1971).

RECENT DATA ON BEACH PROCESSES

Longshore transport:

Some experiments on longshore transport of pebbles have also been undertaken along the length of beach between West Bexington and West Bay. In March 1973 the (then) Unit of Coastal Sedimentation, now part of the Institute of Oceanographic Sciences, carried out trials at Freshwater Beach (approximately 1 km SE of Burton Bradstock in Figure 1). These proved inconclusive.

Jolliffe (1979) describes qualitative experiments extending over 18 months using simulated pebbles incorporating fluorescent particles at West Bay. The results suggest that while labelled material travels from E to W, ie the opposite direction to that shown as the general trend in the Wyke Regis area, it does not move in the reverse direction. The Hydraulics Research Station (1969; 1979) also expressed this view in part because shingle extended further seaward along the E jetty of the West Bay harbour approach than along the W jetty It had been formulated in the 1955 and 1966 Public Inquiries.

The data from investigations at Wyke Regis, Portland and West Bay thus give totally different results. It is suggested here that the Portland ones are a fair representation of the processes occurring but the Wyke results may be slightly biased by the grades of pebbles and cobbles employed. Jolliffe's West Bay tracer programme may have been complicated by the unrepresentativeness of the labelled material; the lack of beach material to the W of the jetties; the tendency of pebbles to infill extraction sites, and the localised hydraulic conditions at the harbour entrance. However, if the evidence provided by longshore grading of the indigenous beach material is accepted then the

Freshwater and West Bay locations are outside the limits of the present-day Chesil Beach sediment transport system. This is the conclusion that would also be drawn from the suite of tracer experiments if taken at their face value.

Changes in the height of the beach crest:

It has been observed above that there were variations in the crest height of Chesil Beach between 1852 and 1968-9. Nevertheless data suggest that, apart from the uneasy junction between the rigid sea wall at Chiswell and the flexible natural defence of Chesil Beach itself, the beach crest remained remarkably stable for a long period prior to the 1978-79 winter. However, in the course of that winter there were two flooding events the second of which, in particular, was accompanied by substantial modification of the beach crest. That in December was attributable to short-period storm waves and the other, in February, due to long-period swell.

During a fairly typical year (1965-66) a series of sections were taken at various times and locations along Chesil Beach. These showed that some of the short-term changes on the seaward face of the beach were of the same order as those which occurred between Coode's surveys of 1852 and that date. While during 1965-66 it was possible for the swash from waves to reach the beach crest it did so without any residual energy and the crest-line remained virtually unaltered. This situation appears to be quite common, thus wrack is deposited at or near the crest on perhaps one occasion in most years. Nevertheless, as Figure (2) shows various other surveys confirm that the crest-line itself in the apparently most susceptible area remained unaffected during the whole period between October 1955 and September 1978. Throughout this time even detailed topographic forms were retained except adjacent to the sea wall junction. Figure (3) comprises a number of cross-sections surveyed in 1965 and 1977. Apart from small changes at the crest on Section 6 the only real differences relate to the seaward slope. Nevertheless, as indicated above, substantial changes have taken place over the longer term. In their 1972 paper the present writer and Ray Gleason found difficulty in explaining this phenomenon although it helped give credence to early 19th century reports that the beach used to be over-topped more frequently. A comparison of the 1968/9 profile and associated data with that of March 1979 shows that the single winter 1978/9 was capable of producing the same order of change at the SE end of Chesil Beach as that indicated between 1852 and 1968/9. Thus at one location there was a maximum fall of 2.7 m in crest height between September 1978 and March 1979, making a total lowering of 3.4 m between 1852 and 1979. Coupled with the known stability of the crest between 1955 and September 1978 it suggests that one event would be enough to produce the scale of change observed over the period 1852 to 1968/9. Such an event appears to have occurred in 1904 under similar long period swell conditions to those recorded on

13 February 1979. In both instances there was no local storm but a depression in mid North Atlantic travelling at such a speed that it generated high waves of unusually long period and large wavelength. These were directed up the English Channel and, at least in the case of February 1979, coincided with spring tides and a relatively large surge.

A possible mechanism to account for these height changes is that where a typically large swell wave arrives at right angles to the beach, the crest is overtopped, lowered, and pushed inshore (ie towards Portland Harbour). Further W, towards Abbotsbury, swell would arrive more obliquely so that instead of moving pebbles from low water mark, over the crest, and down the backslope the material would simply be transferred from the face to the crest by which time the wave energy became expended. In the course of this operation the crest would become higher than before and there would be some net longshore transport of pebbles towards the E.

Between the 1850's data of the Admiralty and Sir John Coode, and that of 1968/9, Carr and Gleason could only find one stretch of the beach where landward recession, of some 17 m, was greater than the possible plotting errors for the scales of the respective surveys. This was close to the narrowest beach width opposite Portland Harbour and roughly coincides with the site of Coode's Sections 6 and 7 shown in Figures (1) and (2). Some of the recession there can be attributed to the relatively frequent storm waves. These had already resulted in the restoration of a near-natural backslope to Chesil Beach between the laying of a water main in 1942 and the 1978/9 winter. Nevertheless the localised retreat of the crest SE of this location as far as Chiswell during the February 1979 event was of the same magnitude as the long-term recession opposite Portland Harbour. It is interesting, too, to note the way in which only certain parts of the crest were modified during 1979 as shown in Figure (2). These presumably coincide with the main focus of the waves for that storm. Elsewhere even under the extreme conditions prevailing on 13 February, the net change to the crest line remained minimal. Thus different stretches of the beach respond preferentially to different events.

Attempts have been made to assess the frequency of events such as that of February 1979 using oceanographic data, and the results have given a return period of between 50 and 70 years. However, this event was due to a high swell of quite exceptionally long period (nearly 20 seconds), combined with a meteorological surge of over 0.5 m, and spring tides. It is not certain what other combinations of conditions might produce similar results, so the frequency estimate has to be regarded as subject to considerable uncertainty. The historical data base is inadequate since the only unequivocal records of such events are for those of 1904 and 1979.

In the geological column it is frequently the atypical event which is recorded. More normally, erosion and accretion tend to cancel each other out. The situation is more acute along much of the British coastline where present-day conditions appear to be biased towards long-term net erosion. Thus a major occurrence such as the increase in crest height along much of Chesil Beach between 1852 and 1968/9 is of special interest. So, too, is the dramatic erosion and flooding of the 1978/9 winter. They emphasise the difficulty of applying suitable time scales to site investigations for civil engineering works and the scale of resources, which would need to be devoted to protection against remote, largely unquantifiable, contingencies.

Short-term versus longer term changes in beach volume

Sir John Coode (Coode 1853) calculated that the temporary loss of material from the beach to the zone immediately offshore following a gale in February 1852 was 3.82 M tonnes. This compares with an apparent loss of 3.05 M tonnes, between the 1965 and 1977 surveys. This drawdown represents a substantial proportion of the beach above mean sea level and appreciably more of that in front of the beach crest.

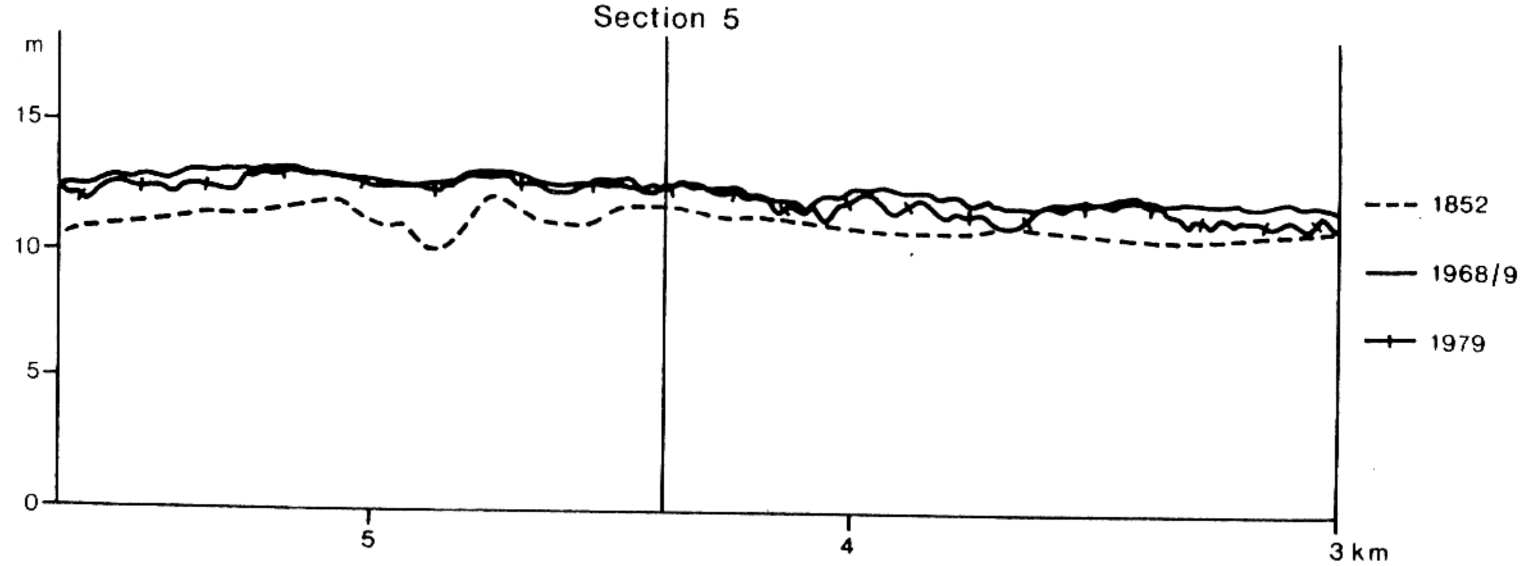
'Pebble-picking' of selected grades of beach material took place in the Chiswell area from at least the late 1940's until 1973. Although quantities removed were relatively small, typically 350 tonnes per year, they are likely to have had a marginal effect on the stability of the beach there as well as an influence on the local longshore beach grading. However, by far the greater extraction of pebbles has occurred from W of Abbotsbury to as far as West Bay, Bridport. Records show (Jolliffe 1979; Carr 1980) that between the mid-1930's and 1977 some 1.1 M'tonnes were known to have been extracted for commercial purposes. If we take the quantity of pebbles and cobbles in Chesil Beach as 50 M tonnes then the losses due to human agency since the mid-1930's are somewhat over 2 per cent taking the beach as a whole; the proportion would be far greater if the western portion alone were considered. No-one knows how this compares with the natural rate of attrition of the pebbles and cobbles which comprise Chesil Beach.

ACKNOWLEDGEMENTS

I would like to thank Dorset County Council, Nature Conservancy Council and Weymouth and Portland Borough Council for the use of data incorporated in Figures 2 and 3.

Note: Comprehensive references to Chesil Beach are given in Carr and Blackley (1974). Those specifically referred to in the present Chapter are incorporated in the consolidated list at the rear of the volume. So, too, are a few additional published references located since 1974.

(a)


Section 5
m
15
10
5
0
5
4
3 km
1852
1968/9
1979

(b)

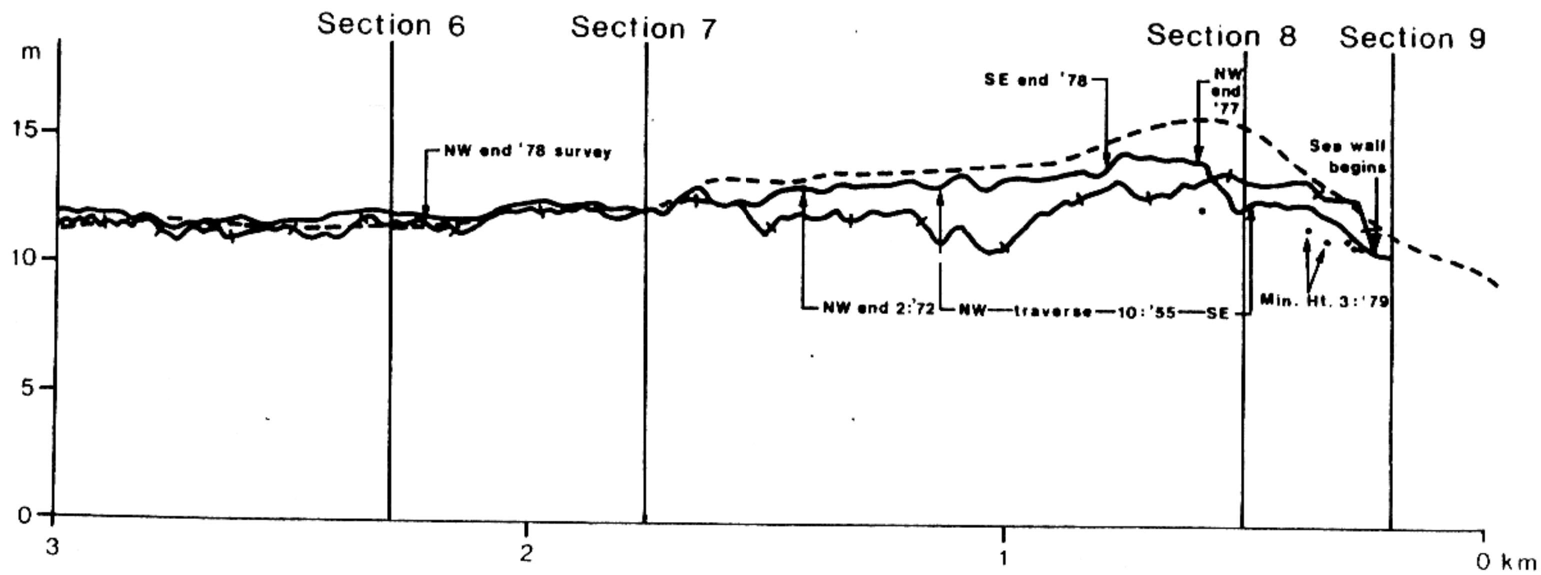
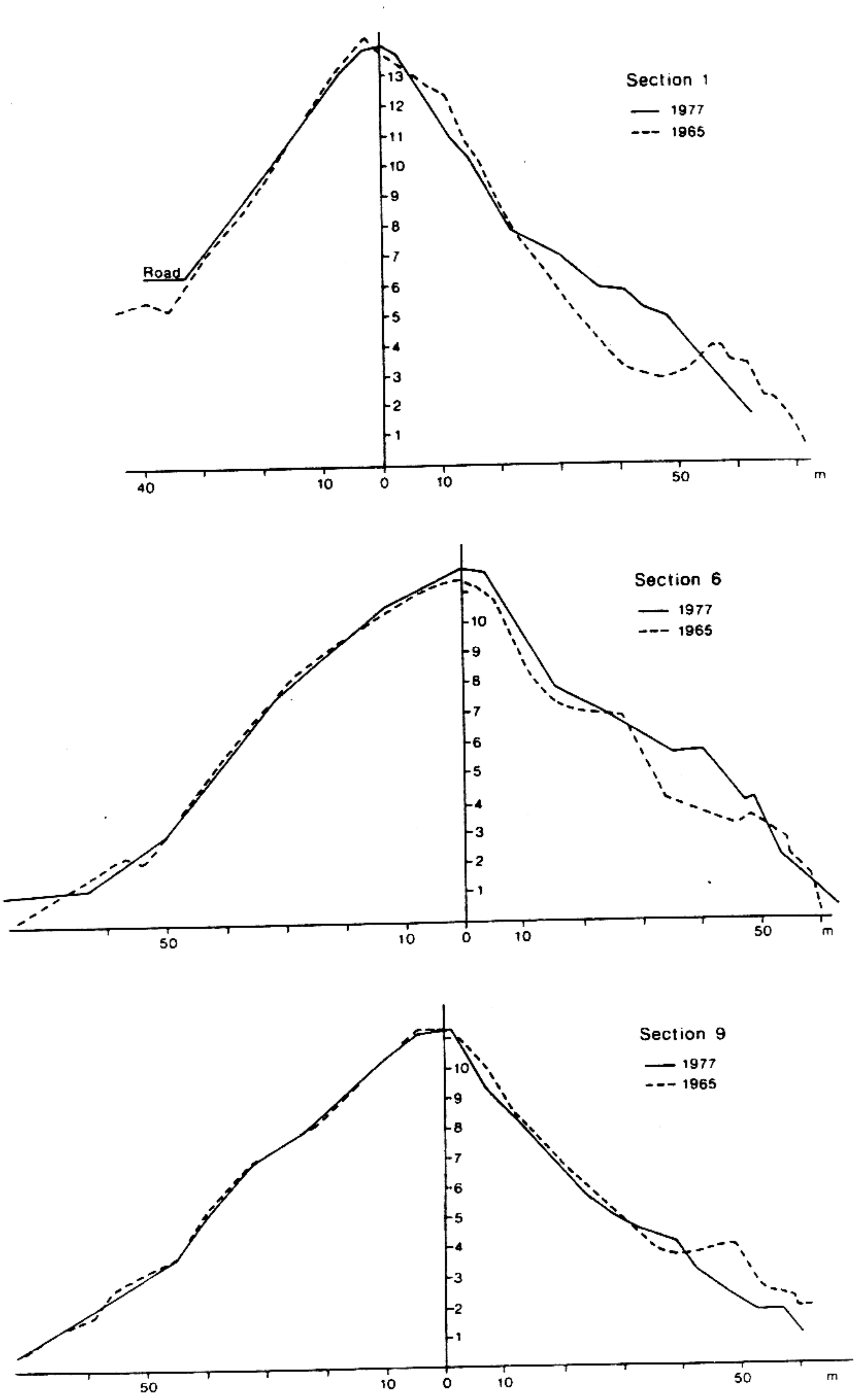

Section 6
Section 7
Section 8
Section 9
m
15
10
5
0
3
2
1
0 km
NW end '78 survey
SE end '78
NW end '77
Sea wall begins
NW end 2:'72
NW—traverse—10:'55—SE
Min. Ht. 3:'79

Fig 2

Fig 3



Section 1
1977
1965
Road
1
2
3
4
5
6
7
8
9
10
11
12
13
40
10
0
10
50
m
Section 6
1977
1965
1
2
3
4
5
6
7
8
9
10
50
10
0
10
50
m
Section 9
1977
1965
1
2
3
4
5
6
7
8
9
10
50
10
0
10
50
m